Quantifying the effects of climate change on the Navajo Nation

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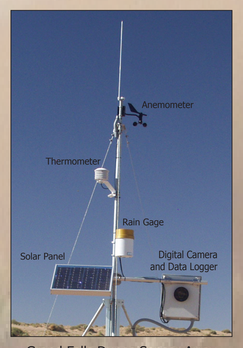
Overview

Native Americans of the southwest live on ecologically sensitive semiarid to arid lands with limited natural resources. On the 6,500,000 hectare Navajo Nation in the southern Colorado Plateau, traditional people often live a subsistence lifestyle, relying heavily on those available resources. Increased temperature and changing precipitation are transforming the landscape and thereby negatively impacting the residents. For people to inhabit these lands successfully, we must both understand the processes that are rapidly altering these drylands and develop mitigation strategies.

Annual rainfall in the western Navajo Nation has fallen below 80 mm during the most recent drought. As a result, the areal extent of sand susceptible to mobilization has increased significantly and regionally significant dust storms emanating from the study area are becoming common. Initial data indicate sand dune migration rates are in excess of 35 m/yr, and initial assessments indicate reactivation of formerly stabilized surfaces, endangering housing and transportation, jeopardizing native plants and grazing lands, increasing natural and human health hazards, and impacting regional air quality.

Sensor Arrays

We are employing a suite of technologies and methodologies to record, assess, and model the interactions among climate variations, landscape sensitivity to eolian processes, and landscape response to changes in native as well as invasive vegetation. A record of climate variables along with coincident landscape and phenological change data are being gathered through a network of meteorological stations and in-situ automated cameras, in addition to repeat high-precision GPS and terrestrial Lidar surveys, and high-resolution remote sensing assessments.



Grand Falls Dunes Sensor Array

Four sensor arrays in the southwestern Navajo Nation allow the collection of site specific data , illuminating these on-going processes. At the Grand Falls dune field, a digital camera, protected by a fiberglass housing, provides visual evidence of dune movement. Triggered at 10 minute intervals when the co-located anemometer detects average wind speeds in excess of 4.5 m/s, the camera can capture both dust storm events and dune movement.

soil moisture probe

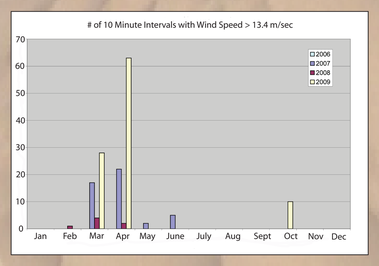
soil moisture probe installation

A soil moisture probe accompanies rain and temperature gages in the array, enabling the correlation of rainfall and temperature fluxuations to changes in dune water content; critical information in our efforts to understand how moisture in sand dunes varies with climate and vegetation growth.

Grand Falls sensor array with dune field in the distance

Grand Falls dune field stand-alone anemometer

A stand-alone anemometer, located 1 km south of the sensor array, provides wind speed data at the southern edge of the Grand Falls field, allowing the analysis of any effects of dune topography on wind speed within the field.



The anemometers in the arrays provide critical data for any analysis of changes in the regional wind speed regime. As shown in this graph, wind intensity varies greatly by season in the Navajo Nation, with late Winter and early Spring having the highest sustained wind velocities. Annual variations can also be extreme, with 2007 and 2009 having more intense wind events than 2006 or 2008.

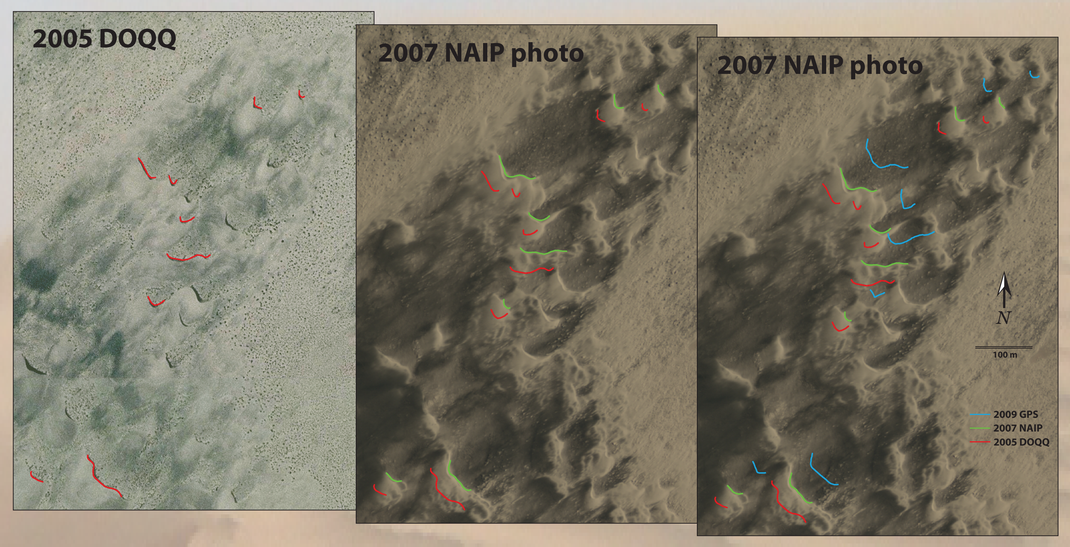
BSNE particle collector

Other weather instrument sites have been estabished to the north and east of Grand Falls. One of the eastern locations, at Teesto Wash, also includes a BSNE particle collector, allowing estimates of sand movement relative to monthly changes in wind energy.

With sand dune migration and dust emission issues providing challenges across the entire Navajo Nation, we hope to eventually expand the sensor network beyond the southwestern portion of the Nation. Having the array provide these data from all corners of the reservation will allow a more comprehensive understanding of the processes driving regional sand and dust movements.

Historical Aerial Photo Analysis & GPS Surveying

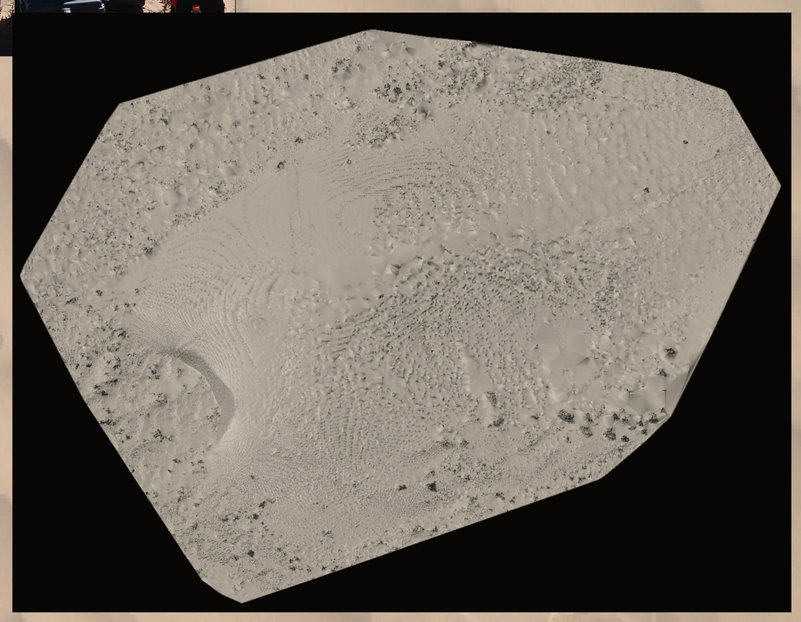
Making use of georeferenced historical aerial and satellite photographs, dune field and individual dune slip face movements have been mapped. Survey grade GPS instruments now allow the mapping and monitoring of dune slip faces to within 5mm while providing great flexibility in timing data collection efforts.



In the example above, dune slip face locations as of 2005 were mapped using USGS DOQQs, then mapped again using NAIP photography taken in 2007. The final image includes slip face locations acquired in 2009 using GPS instruments. Dune movements within the field over this 4 year period averaged over 20m/year, with some of the northernmost dunes moving 70m between 2007 and 2009.

Ground-Based LiDAR

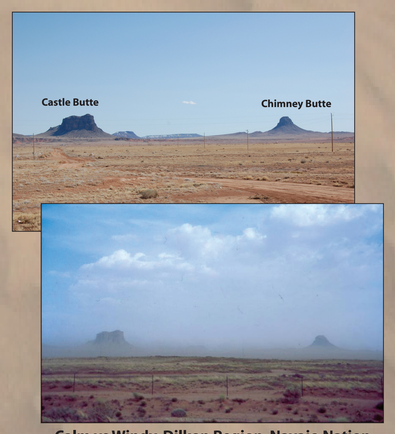
A ground-based LiDAR instrument is being used to track volumetric changes in two individual dunes within the Grand Falls dune field. The LiDAR instrument, set to collect data at six locations surrounding each dune, records millions of XYZ point locations during its scans, allowing the creation of highly detailed 3D models of the dunes. Repeat scans, before and after the windy Winter/Spring season, allows analyses that will help us understand geomorphic changes of the dunes they move across the landscape.



The 3D dune surface models created with the LiDAR data will also be compared to similar models created from stereo images taken with a digital camera. Because creating 3D models with stereo images is more time and cost effective when compared to methods relying on LiDAR hardware, successful use of the stereo images in surface modeling would provide a valuable tool to the project. Trials are also being done with the LiDAR instrumentation in an effort to create elevation models of the entire dune field from the ridge line overlooking the dunes.

Conclusions/Summary

A more complete understanding of the complex environmental processes that have such a profound influence on the Navajo Nation requires robust data sets. USGS scientists in Flagstaff, with the cooperation of the Navajo people, are working to expand the sensor network in the southwestern Navajo Nation and concurrently develop new data analysis techniques. As our instrumentation network grows and data collection/analysis protocols are refined, the resulting analyses will provide the Navajo people with information to better manage and mitigate the challenges that they will face as their Nation's landscape changes over time.



Calm vs Windy, Dilkon Region, Navajo Nation

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